

Evaluation of Lead Content in Paints and Contaminated Soils by Atomic Absorption Spectroscopy

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ABSTRACT: Lead is a neurotoxin that accumulates both in soft tissues and the bones. Lead exposures have developmental and neurobehavioral effects on fetuses, infants and children and elevate blood pressure in adults. Impairment of neurodevelopment in children is the most critical effect. Lead and its compounds are used in paints not only to impart colour but also to make it durable, corrosion resistant and improve drying. Adverse health impacts of lead have led countries to restrict to use it in paints. Developing countries including India have failed to regulate their lead content. Our present study was undertaken to determine the levels of lead in new enamel paints intended for residential use in India from some major manufacturers and to analyse soil near painted walls for the lead content.

KEYWORDS: Neurobehavioural effects, lead estimation.

I. INTRODUCTION

Lead is a naturally occurring high metal found in earth's crust. Its widespread use has resulted in extensive environmental contamination, human exposure and significant public health problems in many parts of the world. Important sources of environmental contamination including mining, smelting, manufacturing and recycling activities and in some countries, the continued use of lead paints, leaded gasoline and leaded aviation fuels. Young children are vulnerable to the toxic effects of lead and can suffer profound and permanent adverse health effects, particularly effecting the development of brain and nervous system. Lead also causes long term harm in adults, including increased risk of high blood pressure and kidney damage. Exposure of pregnant women to high levels of lead may cause miss carriage, still birth, premature birth and low birth weight as well as minor malformations.

Typical lead paints in the early 20th century contain as much as 40 to 50% lead; however by the mid-20th century the use of lead in paint pigments was sharply reduced and replaced with Titanium dioxide and zinc oxide. Several paint standards were also established. We suspect that lead is heavily used above standards in modern paints available in India.

People may be exposed to lead through occupational and environmental sources. This mainly results from:

- Inhalation of lead particles generated by burning materials containing lead, i.e. during smelting, recycling, stripping leaded paints etc.
- Ingestion of lead contaminated dust, food or water.

Young children absorb 9.5 times ingested lead higher than the adults. Moreover, children innate curiosity and their age appropriate hand to mouth behaviour results in their mouthing and swallowing lead containing objects, such as contaminated soil or dust and flakes from decaying lead containing paint. Once lead enters the body it is distributed to

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organs such as brains, kidneys, liver and bones. The body stores lead in the teeth and bones where it accumulates overtime. Lead stored in bone may be remobilized into the blood during pregnancy, exposing the foetus.

Paint is composed of two basic ingredients: pigment and a binder, a solvent (thinner) generally added to change the application characteristics of the liquid. Pigments are insoluble solids, incorporated into the paint to contribute colour, texture or some other characteristics. Opaque pigments give the paint its hiding or covering capacity and contribute other properties. White lead, zinc oxide and titanium dioxide are examples. The major lead containing pigments include white lead, red lead, leaded zinc oxide, chrome green chrome yellow, and chrome orange. Lead is present in these pigments as oxides, carbonates, hydroxides and chromates. Vehicles or binders are the material holding the pigment together and causing paint to adhere to the surface. As pigment lead(II) chromate ($PbCrO_4$, Chrome yellow), lead(II, IV) oxide (Pb_3O_4 , red lead) and lead(II) carbonate ($PbCO_3$, white lead) are the most common forms. Lead is added to paint to speed up drying, increase durability, maintain a fresh appearance and resist moisture that causes corrosion.

The domestic paint available today contains only very small quantities of lead and is unlikely considered to be a hazard. Several paint removal methods particularly power sanding and dry abrasive blasting generates high concentrations of dust and fumes which are dissipated widely. Air ambient concentrations of lead during the paint mixing, paint spraying etc. cause anthropogenic spread of poisons. Dissolution of lead in rain water can also increase lead accumulation in soil.

Regulations for lead in paints:-

International: - The harmful effects of lead have been well known for over 100 years. Many countries investigated lead poisoning and recommended the substitution of non-lead pigments that were available. Countries that restricted the use white lead in paints include France, Belgium and Austria in 1909; Tunisia and Greece in 1922; Czechoslovakia in 1924; Great Britain and Sweden in 1926; Poland in 1927; Spain and Yugoslavia in 1931; and Cuba in 1934. In 1922 the third international labour conference of the League of Nations recommended the banning of white lead for interior use.

India: - The paint industry is regulated by the Bureau of Indian Standards for the maximum content of lead in paint and is governed by IS 2932:2013 for ENAMEL, SYNTHETIC, EXTERIOR: (a) UNDER COATING (b) FINISHING – SPECIFICATION; PART 1 FOR SOMESTIC AND DECORATIVE APPLICATIONS. Superseding IS 15489:2004, IS5411 (part 1):1974 and IS5411 (part 2): 1972. The specification states that,

“In this revision, lead restriction up to a maximum permissible limit of 90ppm has prescribed keeping in view to use this product for painting in houses and buildings”.

Regulations for lead in soil:- There is no strict regulation for lead in soil. Lead is naturally available in soil range from 10 to 50 mg/kg equivalent to ppm. The environmental protection agency (EPA) is standard for lead in bare soil in play areas is 400ppm by weight and 1200ppm for non-play areas.

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II. RELATED WORK

Sl no.	Source	Key Findings
1.	WHO(2007) Health risks of heavy metals from long range Transboundary air pollution.	<ul style="list-style-type: none"> Major health effects by atmospheric lead pollution. Sources of lead pollution.
2.	Bureau of Indian standards	<ul style="list-style-type: none"> Estimation of lead, IS 6947 part 3:1975 Methods of tests. <ul style="list-style-type: none"> Lead and scarlet chromes IS 50: 1980 IS 15489:2013 Paint, plastic emulsion specification.
3.	Dr Abhay Kumar "Brush with Topics, An investigation on lead in household paints in India". September 2007.	<ul style="list-style-type: none"> Use of lead in paints. Paint composition. Paint industry in India Toxicity mechanism of lead. Regulations for lead in paints. Sampling methodology.
4.	Md. Lokman Hossain, Mohammed Abdus Salam, Satyajit Roy Das, Md. Iqbal Hossain, Sultana KamrunNaharNahida, ShamimAkterMamun, SnigdhaTalukder and MaksudaKhanam., "Lead Content of Enamel Paints in Leading Paint Companies in Bangladesh", IOSR Journal Of Environmental Science, Toxicology And Food Technology, Volume 3, Issue 1 (Jan. - Feb. 2013).	<ul style="list-style-type: none"> About lead. Substitutes of lead in paints. Material and methods. Calculations.

III.METHODS

1. Samples

A. Paint Samples

Paint samples from 3 different manufacturers such as Asian paints, Berger and British paints were collected. Deep orange, black, white, yellow were the colours. A total of 11 enamel paint samples were collected (fig 1).

B. Soil Samples.

Soil samples were collected from 3 various locations. Samples were collected from each location from 0-5cm deep, 10-15cm deep and 20-25cm deep.

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Fig 1: Paint samples

The figure shows the paint samples selected for the analysis of different manufacturers and colours.

2. Experimental Method

A. Preparation of standard lead solution:

Three standard solutions of known concentrations were prepared from a stock solution of $\text{Pb}(\text{NO}_3)_2$ (1.598g $\text{Pb}(\text{NO}_3)_2/1000\text{ml}$). The concentrations of these three solutions were 3ppm, 5ppm and 7ppm (Fig 2).



Fig 2: Standard Lead Solutions

The figure shows the standard lead solutions taken as the standard reference solution. The solutions are 3ppm, 5ppm, 7ppm $\text{Pb}(\text{NO}_3)_2$.

B. Preparation of dried paint scrapings:

Paint samples were spread on watch glasses and dried in an oven at 70- 80⁰C for several hours. From each dried samples 0.30g of dried paint scrapings were taken and made into solution with concentrated Nitric Acid. The undissolved paint residues are filtered and the solution is made up to 100ml with distilled water (Fig 3).

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Fig 3: Diluted Paint Samples

The figure shows the diluted paint samples. The concentrated nitric acid dissolved paint solution is diluted using distilled water for comparison with the standard solutions in the AAS.

C. Preparation of soil samples

Soil samples were screened to remove unwanted debris. Soil samples were dried in petri dishes in an oven at 70 – 80°C for several hours. 10gm of dried soil is taken in a beaker and then digested using 10ml of aqua-regia($\text{HNO}_3:\text{HCl}$, 1:3). Samples were then filtered and quantitatively transferred to volumetric flask and made up with distilled water to a total volume of 250ml (Fig 4).



Fig 4: Diluted soil samples

The figure shows diluted soil samples. The soils digested using concentrated aqua-regia are diluted for comparison with standard lead solutions and to prevent damage in AAS.

D. Measurement of Absorbance of samples

Atomic absorption spectrophotometer was set to wavelength of 217nm with a slightly oxidising Air-Acetylene flame.

The solutions were aspirated into the spectrophotometer and three absorbences per sample recorded for each of the standard solutions, duplicate paint sample solutions and soil sample extract solutions.

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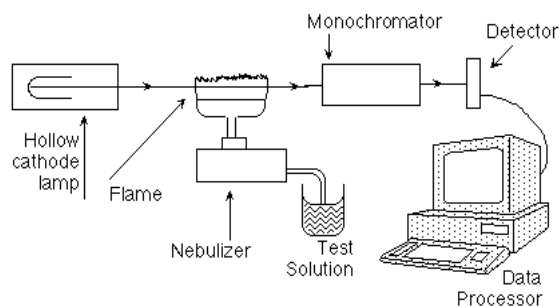


Fig 5: Schematic Diagram Of an Atomic Absorption Spectroscopy(AAS)

The figure shows the schematic diagram of AAS used for testing paints and soils to find the lead concentration using flame emission absorption.

IV. RESULTS AND DISCUSSIONS

A. Paint Samples:

Sample	lead content in ppm	Remarks	Information From Paint Can
AP BLZ White	226.95	High	No lead added
BRP Tower Orange	2356	Very high	No lead added
BRP Gold Yellow	749.3	Very high	No lead added
AP Orange	66.93	Below limit	No lead added
BP Deep Orange	12129	Dangerously high	No lead added
BP Snow White	71.25	Below limit	No lead added
BRP Ultra White	113.25	Above limit	No lead added
AP Black	104.1	Above limit	No lead added
AP gold Yellow	172.8	High	No lead added
BP Gold Yellow	127.3	Above limit	No information
BP Black	111.6	Above limit	No lead added

Abbreviations used: AP- Asian Paints, BRP- British Paints, BP- Bereger Paints.

The table above shows the amount of lead found in various paints analysed. The remarks given in red indicates the lead content above the prescribed limit. The green remarks indicates within level. Most of the cans were labled as “No lead added”.

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B. Soil Samples:

Sample	Pb content in mg/kg	Remarks
I : 0 – 5cm	171.305	High, above normal
I : 10 – 15cm	5.6725	Below normal
I : 20 – 25cm	39.98	Below normal
II : 0 – 5cm	56.50	Above normal
II : 10 – 15cm	61.52	Above normal
II : 20 – 25cm	56.417	Above normal
III : 0 – 5cm	80.787	Above normal
III : 10 – 15cm	107.2175	High, above normal
III : 20 – 25cm	99.6	High, above normal

Abbreviations used: I- Soil Sample I, II- Soil Sample II, III- Soil Sample III.

The table above shows the lead content in soils from different locations and different depths. The red remarks indicate the lead content above the normal level. The green remarks indicate within level.

Initially 11 samples of popular enamel paints and soils were analysed for lead with a widely and internationally used methodology by AAS.

Lead was found in all the samples of paints and soils. Out of 11 paint samples 9 were found to be above the prescribed level (IS2932:2013) and out of 9 soil samples 7 were found to be above normal level of lead in soil.

Except Berger Golden Yellow can, all other cans state that no lead was added, but from our results, all the paints were found to be added with lead.

The average concentration of lead in all the 11 enamel paint samples range from 66.93 to 12129ppm. Highest concentration of lead (1219ppm) was found in Berger paint deep orange, which is about 135 times higher than the limit. Lowest concentration were found in Asian paint orange. In our evaluation samples Asian paint orange and British paint snow white were within the limit of lead content.

Lead in soils ranges from 5.6925 to 171.305mg/kg. Highest concentration (171.305mg/kg) was found in soil sample I at 0-5cm depth. Soils from the same place little deeper i.e. 10-15cm and 20-25cm has only small quantities of lead, this suggests that a leaded paint might have been used on the wall recently. Soil sample III at a depth of 10-15 cm have double the amount of lead present naturally. This suggest that a leaded paint might have been used many years ago. Upper layer at 0-5cm depth has lower lead content which indicates that the new paint might have lower lead content or the wall is not painted recently.

The average concentration of lead for orange enamel paints was 4850.643 ppm, yellow 349.8 ppm, white 137.15 ppm, and black 107.85 ppm. The lead content in different colours of enamel paints in decreasing order is as follows:

Orange > Yellow > White > Black

V. CONCLUSIONS

- All the samples contain lead and 81% of paint samples were above prescribed limit and 77% of soil samples were above normal lead content.
- In the order of decreasing lead accumulation in paints can be arranged as follows:
Orange > Yellow > White > Black
- There is no regulation in India for labelling the hazardous contents on paint containers. Hence there is an urgent need in the awareness of the harmful effects of lead especially in households due to the lead based paints.

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VI. RECOMMENDATIONS

Lead can be replaced by Titanium oxide and Barium-Zinc-Sulphur combinations and their durability can be improved by adding Silicon and oxides. The increase in cost of substituents is relatively small and can't be compared with the harm caused to human beings due to continuous exposure to lead.

The government must lay down effective guidelines for manufacturers and users to minimize the trail and impact. Manufacturers must share the market intelligence and information with public. Following steps can be considered for minimizing the hazards of lead paints.

A. Regulation :-

It is inevitable to enact mandatory national regulations for limiting lead concentrations below 90 ppm in paints.

B. Monitoring :-

For effective implementation of lead standards, a proper monitoring plan should be devised to ensure that the industry complies with the standards. The government agencies in collaboration with non-governmental organisation can play a key role in monitoring the presence of lead in paints.

C. Legacy issues :-

Paint industry and health care professionals should give guidelines to reduce exposure to lead while removing old paints or recoating with new one.

D. Public awareness :-

A mass awareness campaign should be launched to reduce and make people aware of the hazards associated with lead. So that they try to purchase lead free paints.

E. Levelling:-

The paint industry should include a lead free paint symbol on products as well as guidelines for use including for home decorative or industrial and commercial.

F. Certification :-

A third party certification for paint manufacturers can be an ideal approach to reduce lead in paints.

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